FTD-ID(RS)T-1710-83

FOREIGN TECHNOLOGY DIVISION

TURBULENT STRUCTURE OF ROTATING STREAMS

by

B.P. Ustimenko, V.N. Zmeykov, M.A. Bukhman

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FTD-ID(RS)T-1710-83

EDITED TRANSLATION

FTD-ID(RS)T-1710-83 3 February 1984

MICROFICHE NR: FTD-84-C-000126

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English pages: 9

Source: Izvestiya Akademii Nauk Kazakhskoy SSR, Seriya Fiziko-Matematicheskaya, Nr. 6, 1967, pp. 27-30

Country of origin: USSR
Translated by: Robert Allen Potts
Requester: FTD/TQTA
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А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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TURBULENT STRUCTURE OF ROTATING STREAMS.

B. P. Ustimenko, V. N. Zmeykov, M. A. Bukhman.

The investigation of turbulent structure is necessary for understanding the physical mechanism of transfer processes in rotating streams, their peculiarities and distinctions from rectilinear flows, for solution of questions of the intensification of carburetion, combustion etc.

For the purpose of revealing the main characteristic perculiarities of the effect of the field of centrifugal forces on the processes of turbulent transfer, research of the aerodynamics and heat exchange of circular flow in annular channels between rotating cylinders was conducted. In this case were examined two limiting cases of the relationship of angular velocities of rotation of external and internal cylinders, equal to zero (only the internal cylinder rotates) - unstable flow and to infinity (external cylinder rotates) - stable flow.

The distributions of tangential $(\varepsilon_t = \sqrt{\overline{v_t'^2}}/\bar{w})$, axial $(\varepsilon_z = \sqrt{\overline{v_z'^2}}/\bar{w})$ and radial $(\varepsilon_r = \sqrt{\overline{v_r'^2}}/\bar{w})$ components of relative intensity of fluctuations of velocity*, measured in channels with internal (a) and external (b) rotating cylinder, are presented in Figure 1.

FOOTNOTE * Measurement of fluctuation characteristics of flow was performed by ETAM-3A hot-wire anemometer with ESU-2 amplifier of system VEI [1]. ENDFOOTNOTE

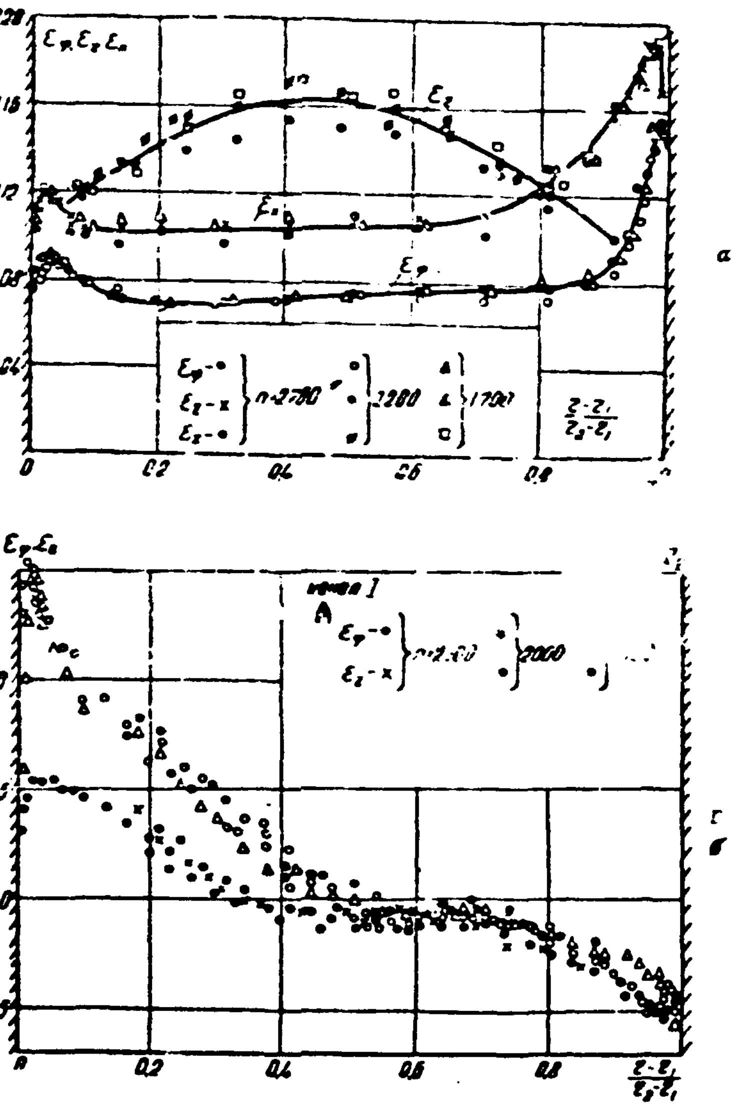

Fig. 1. Profiles of components of relative intensity of fluctuations of velocity in the channel with internal (a) and external (b)

cylinder.

Key: (A) channel.

In the channel with internal rotating cylinder, just as in rectilinear channels, components ε_φ and ε_z take maximum value close to the walls, in the region of the greatest change of average velocity. The greatest value of radial component ε_r is observed in the central part of the channel.

During rotation of the external cylinder ε_φ and ε_r reach maximum value near the rotating wall, and minimum - near the stationary wall. The level of fluctutations in the channel with internal rotating cylinder is significantly higher (3-5 times) than during rotation of the external cylinder.

The substantial difference in the level of intensities of fluctuations of velocity in channels with external and internal rotating cylinder is connected with the different action of the field of centrifugal forces on the fluctuating motion in these cases. In the first case the field of centrifugal forces damps the turbulent fluctuations and stabilizes flow. This leads also to significant reduction (2-3 times) of the resistance and intensity of heat transfer. In the second case the reverse action of the field of

centrifugal forces is observed.

In contrast to flow in the channel with internal rotating cylinder, where turbulization of the stream sets in virtually simultaneously along the entire width of the channel, in channels with external rotating cylinder the turbulence appears first in a narrow band close to the rotating cylinder and in proportion to increase of the speed of rotation is gradually propagated through the entire width of the channel. In this case in a certain range of Reynolds numbers there exist regions of laminar and completely turbulent flow, separated by a region of the periodic appearance of fluctuations. The width of each region is changed with a change of Reynolds number.

The noted qualitative peculiarities of the effect of the field of centrifugal forces on the processes of turbulent transfer in circular flows are observed also in more complex cases of rotating flows, in particular, in cyclone chambers.

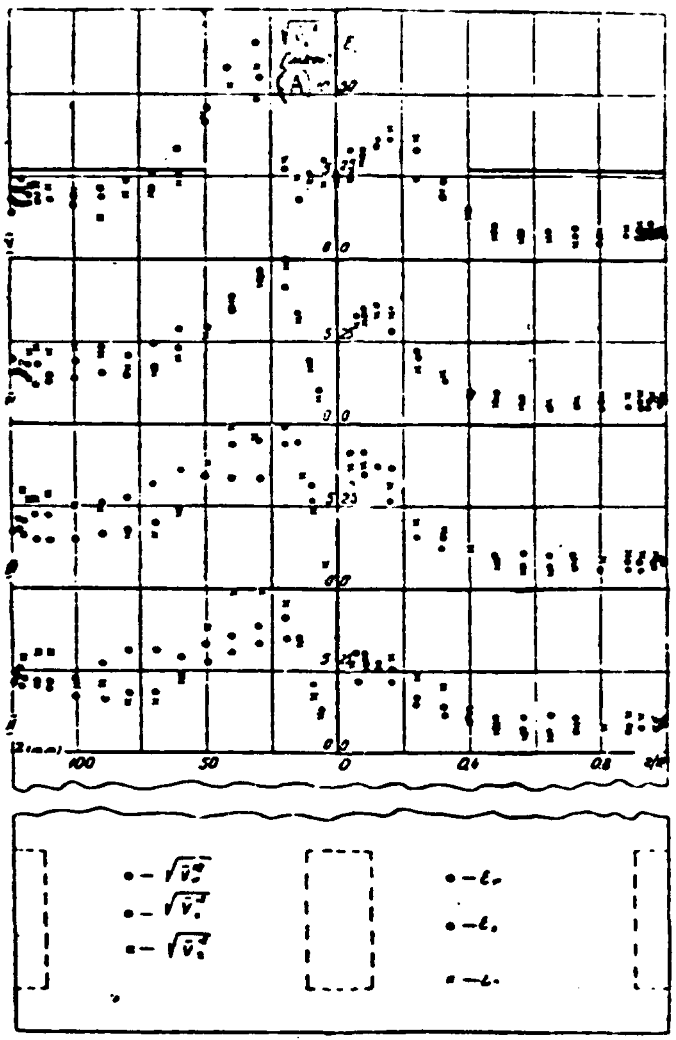

Fig. 2. Distribution of the relative intensity of turbulence ϵ_i and mean-square turbulent fluctuations of velocity $\sqrt{\overline{v_i'^2}}$ in a cyclone

chamber.

Key: (A) m/s.

Fig. 2 shows the distribution of tangential (ε_φ), axial (ε_z) and radial (ε_r) components of relative intensity of velocity fluctuations in different cross sections of a cyclone chamber. As seen from the figure, all three components have qualitatively identical form: approximately constant value in the region of quasi-potential motion (5-10%) and increase in the region of quasi-solid (up to 40%). The coefficients of turbulent viscosity found during the use of experimental profiles of averaged velocity and correlations $\overline{v_r' v_\varphi'}$ and $\overline{v_\varphi' v_z'}$, in the quasi-potential zone are hundreds and thousands of times, and in the quasi-solid are thousands and tens of thousands of times greater than the coefficient of molecular viscosity.

The high level of intensity of turbulent motion, larger values of coefficients of turbulent transfer determine the sharp intensification of the process of combustion in cyclone chambers.

Flow in the quasi-potential zone of the cyclone is qualitatively similar to flow in the channel with internal rotating cylinder. In the near-wall region of cyclone stream, where the tangential velocity

is decreased with increase of the radius, a zone of hydrodynamically unstable flow appears. Due to the action of centrifugal forces here occurs intensification of the fluctuating motion and processes of turbulent exchange. As in the case of flow in the channel with internal rotating cylinder, this leads to the appearance of so-called "quasi-potential" zone of flow, in which the moment of momentum of elements of liquid can be approximately considered as constant. Concerning flow in the quasi-solid zone of the cyclone, here, in contrast to flow in the channel with external rotating cylinder, where $v_z = 0$ further rise of the level of fluctuating motion occurs. This, apparently, is connected with the circumstance that in this region is observed the greatest value of gradients of axial component of velocity (region of blending of forward and counter streams), i.e., are created conditions for intense turbulent exchange. Flow in this zone resembles flow in the stream region of the near-wall stream. However, flow in the quasi-potential zone in such analogy approximately corresponds to the nucleus of the near-wall turbulent stream.

All this confirms the stream diagram of flow in the cyclone chamber developed in work [3].

Article submitted 27 May 1967

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